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Source: Mountain Research and Development, 31(3) : 209-219

Published By: International Mountain Society

URL: https://doi.org/10.1659/MRD-JOURNAL-D-10-00069.1

Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
www.mrd-journal.org

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Natural Resource Use by Humans and Response of Wild Ungulates

A Case Study from Bedini-Ali, Nanda Devi Biosphere Reserve, India

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*We investigated the levels of natural resource use by humans and the consequent response of wild mountain ungulates in the subalpine and alpine habitats of Bedini-Ali, located in the transition zone of the Nanda Devi Biosphere Reserve, India, from 2005 to 2006. The livestock population in the area, livestock dung density, and the number of trees cut, lopped, and debarked by humans were estimated from permanent plots (*n *= 312, 8 visits) laid along transects. Information on wild mountain ungulate distribution, abundance, and habitat use was recorded by monitoring transects (*n *= 7, 1.2–2 km, 217 visits, 325.5 km sampled) and scanning (*n *= 2, 10 replicates, 60 hours effort). Principal coordinates of overall disturbance were classified into 3 classes: low (< -0.04), moderate (≥ -0.04 to <0), and high (≥ 0). Blue sheep (*Pseudois nayaur*) was most commonly encountered [46 sightings, 652 individuals, 10.19 ± 1.20 (number/hour scan)] in the alpine regions, followed by* sambar (Cervus unicolor) *(15 sightings, 18 individuals, 0.65 ± 0.01/km) and Himalayan musk deer (*Moschus chrysogaster*) (3 sightings, 3 individuals, 0.0015 ± 0.001/km) in subalpine areas. Abundance estimates for all wild ungulates were lowest during summer when anthropogenic activities were highest. Density of blue sheep and dung density of* sambar *and musk deer varied seasonally and was inversely related to livestock abundance. Blue sheep were spatially separated from other ungulates on high-altitude steep rocky terrain with low anthropogenic pressure.* Sambar *and musk deer had to share the subalpine and tree line forested habitats with herded livestock. Prior utilization of food resources in summer by livestock and habitat destruction due to other anthropogenic pressures may have negative impacts on the population of wild mountain ungulates in the study area. We recommend adoption of rotational grazing between Bedini and Ali Meadows, reduction in the number of livestock, and reduction in the period of grazing as mitigation measures.*

Keywords: *Anthropogenic pressure; wild ungulates; livestock grazing; abundance and distribution; alpine meadow management; habitat utilization; India.*

Peer-reviewed: *March 2011* ***Accepted:*** *May 2011*

Introduction

From time immemorial, humans have depended on subalpine forests and alpine pastures for their basic needs such as fuelwood, montane bamboo, fodder, and grazing of livestock. Pastoralism has been practiced in the Himalaya for a few centuries, although the intensity of grazing can vary considerably (Kala and Rawat 1999). Pastoralists lead large herds of sheep and goats and small herds of cattle and buffalo to graze in alpine meadows during summer and bring them back to lower altitudes during mid-autumn (Kittur et al 2010). Pack animals such as horses and mules that transport humans or goods also graze in alpine meadows during summer. Although pastoralism has been a traditional practice, recent changes in the economy and growing market forces have influenced livestock composition, number, and the extent of use (Kala and Rawat 1999). Livestock grazing and other anthropogenic disturbances can cause competitive exclusion of wild animals from high-quality habitats because they may be forced to forage in poor habitats and spend more energy to move away from the disturbances that affect their nutritional balance (Schaller 1977).

Ungulates are a major constituent of Himalayan mammalian fauna, and they are also the major prey base for large mammalian predators. They are known to modify their activity pattern in response to habitat differences, seasons, and disturbance factors, and their behavior could be a sensitive indicator of habitat quality, protection, and management (Owen-Smith 1979; Pachlatko and Nievergelt 1985). The western Himalaya is home to 5 species of mountain ungulates, all of which are reported to occur in the State of Uttarakhand. They include the *goral* (*Nemorhaedus goral*), *serow* (*Nemorhaedus sumatrensis*), Himalayan *tahr* (*Hemitragus jemlahicus*), blue sheep (*Pseudois nayaur*), and Himalayan musk deer (*Moschus chrysogaster*). Other ungulates that occur in the western Himalaya but are also distributed widely in other parts of

India are the *sambar* (*Cervus unicolor*), inhabiting mainly well-wooded areas up to 3200 m, the wild pig (*Sus scrofa*), occurring up to 3000 m, and the barking deer (*Muntiacus muntjac*), which usually occurs up to an altitude of 2700 m (Sathyakumar 1994).

Most available information on mountain ungulates in the Uttarakhand region of the western Himalaya is largely based on extensive or intensive surveys (Sathyakumar 1993, 2004; ZSI 1995; Bhattacharya et al 2007) and a few detailed studies (Green 1985; Sathyakumar 1994). A few investigations have been carried out on livestock-wild ungulate interactions in the Greater Himalaya. Sathyakumar et al (1993) assessed the status of Himalayan musk deer and its habitat in Kedarnath Wildlife Sanctuary and found that increasing livestock densities have led to decreasing Himalayan musk deer densities. Mehra (2000) discussed livestock grazing impacts on the biodiversity of Great Himalayan National Park, Himachal Pradesh. Kittur et al (2010) evaluated the livestock grazing impacts on the Himalayan *tahr* population in Kedarnath Wildlife Sanctuary, Uttarakhand, and reported that in addition to affecting the habitat adversely, heavy grazing may cause shortages of food for Himalayan *tahr* during the resource crunch period. Studies dealing with livestock and wild ungulate interactions in the Trans-Himalayas have been carried out by Mishra (2001), Raghavan (2003), Bagchi et al (2004), Mishra et al (2004), Namgail et al (2007), and Shrestha and Wegge (2008). These studies confirmed that livestock grazing and collateral human activities can interfere with resource acquisition by wild ungulates.

The Nanda Devi National Park and the Valley of Flowers National Park have the distinction of being the only 2 protected areas (PAs) in the Western Himalaya that have been declared UNESCO World Heritage Sites for their exceptional natural beauty and high biodiversity values. These 2 PAs form the core zones of the Nanda Devi Biosphere Reserve (NDBR) and are the only 2 PAs in the Western Himalaya that have not been subjected to livestock grazing since 1983 (Sathyakumar 2004). However, areas outside these PAs (buffer and transition zones) are subjected to a variety of human uses ranging from negligible or low natural resource dependency to moderate or high dependency due to livestock grazing, mountaineering, pilgrimage, tourism, and developmental activities.

There is a lack of information on the status of wildlife, particularly ungulates and their habitats, in the transition zone of NDBR where several villages are located and substantial human and livestock populations depend on natural resources. Bhattacharya et al (2009) have investigated the status and distribution of *Galliformes* in Bedini-Ali in the transition zone of NDBR and reported that densities of Himalayan *monal* (*Lophophorus impejanus*) and *koklass* (*Pucrasia macrolopha*) pheasants were lowest in summer when anthropogenic pressures were high. This paper presents the levels of natural resource use by humans and the consequent responses of wild mountain ungulates observed over a period of 1.5 years during 2005–2006 at Bedini-Ali, located in the transition zone of NDBR, Uttarakhand (Figure 1).

Study area

An intensive study area of approximately 20 km^2 was selected in the western region of NDBR, covering the Bedini-Ali to Roopkund areas (79°40′N, 30°12′E). The study area included representative areas of the upper temperate, subalpine, and alpine regions ranging from 3000 to 5000 m altitude for eastern and western aspects with diverse slopes and a range of human and livestock use categories. Vegetation included alpine meadows dominated by grasses such as *Danthonia* and *Poa* spp. and sedges such as *Kobresia* and *Carex* spp. along with different herbs such as *Trachydium-Potentilla-Anaphalis* spp., a tree line zone dominated by *Rhododendron campanulatum*, and subalpine forests dominated by *Quercus semecarpifolia* and *Abies pindrow*. The average temperature of the area ranges between 18 and -10°C, and annual rainfall is around 2000 mm. Four different seasons—spring (April–June), summer or monsoon (July–September), autumn (October–December), and winter (January–March)—were observed. Wild fauna included carnivores—the snow leopard (*Panthera uncia*) and the red fox (*Vulpes vulpes*)—and 4 ungulates were encountered: Himalayan musk deer, blue sheep, Himalayan *tahr*, and *sambar*. Galliforme prey were the Himalayan *monal* and the *koklass*. Domestic livestock using the study area included cattle, buffaloes, goat, sheep, horses, and mules.

Wan and Didhna are the 2 main villages lying west and southwest of the study area. The whole area is used by village residents and their livestock for grazing and natural resource use. Migratory graziers and their livestock visit the area from May to October. Human presence (for livestock herding, pilgrimage, tourism) and livestock grazing, along with cutting, lopping, and debarking of trees and extraction of other natural resources such as medicinal plants by humans, were significant during autumn, followed by spring and summer. The presence of local people was the only disturbance during winter.

Methodology

Rapid assessment surveys were conducted in different parts of the study area to identify zones of human use. Following this, sampling was undertaken along a gradient of human use between 3000 and 4550 m elevation. Seven transects (1.2 to 2 km) were established in the upper temperate and subalpine zones, and at the higher elevations a 7.2-km-long alpine trail was used (Figure 2). The total count of livestock (cattle, buffaloes, goat, sheep,

FIGURE 1 An alpine grassland (A), flock of sheep with shepherd, and wildlife grazing in the study area. (Photos by Tapajit Bhattacharya)

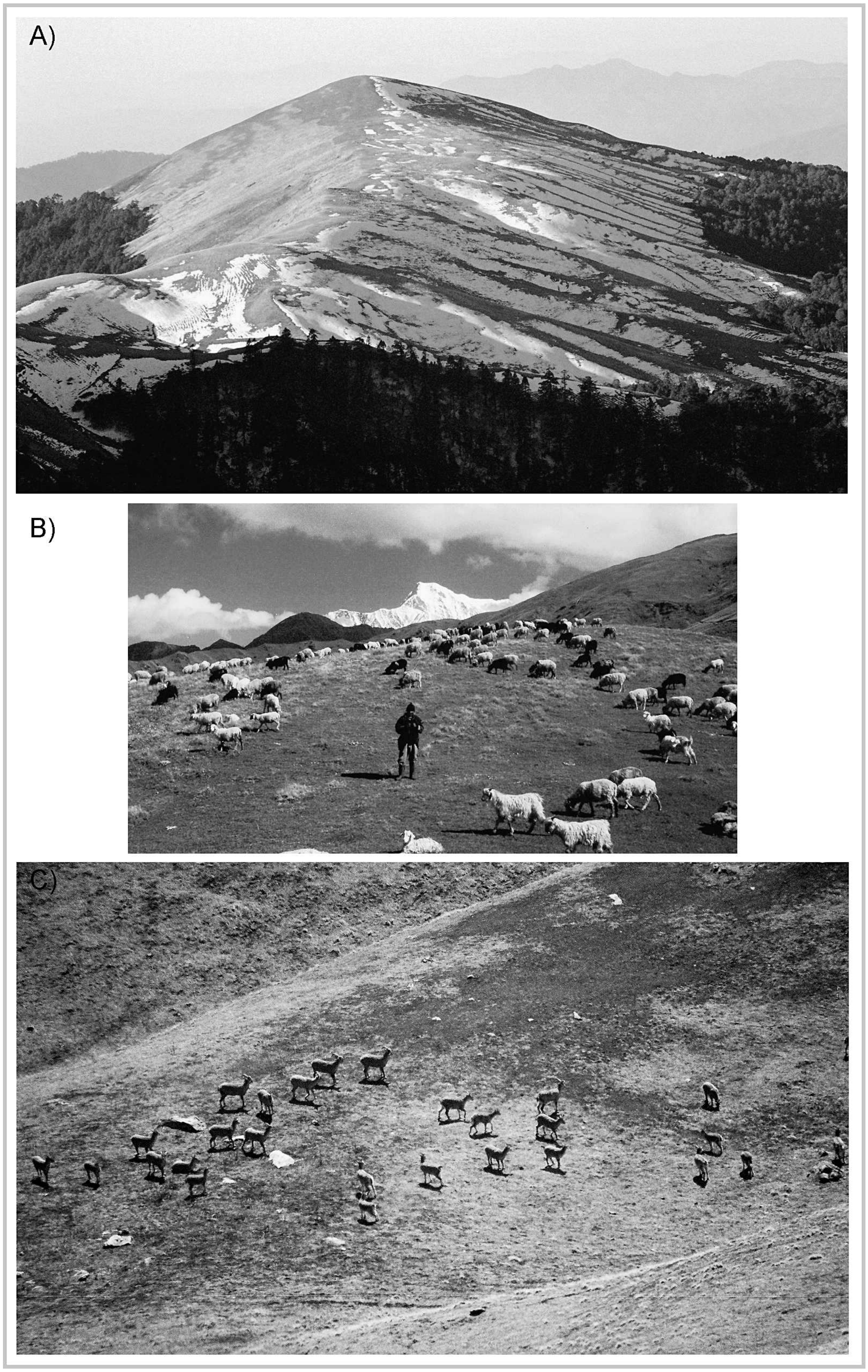
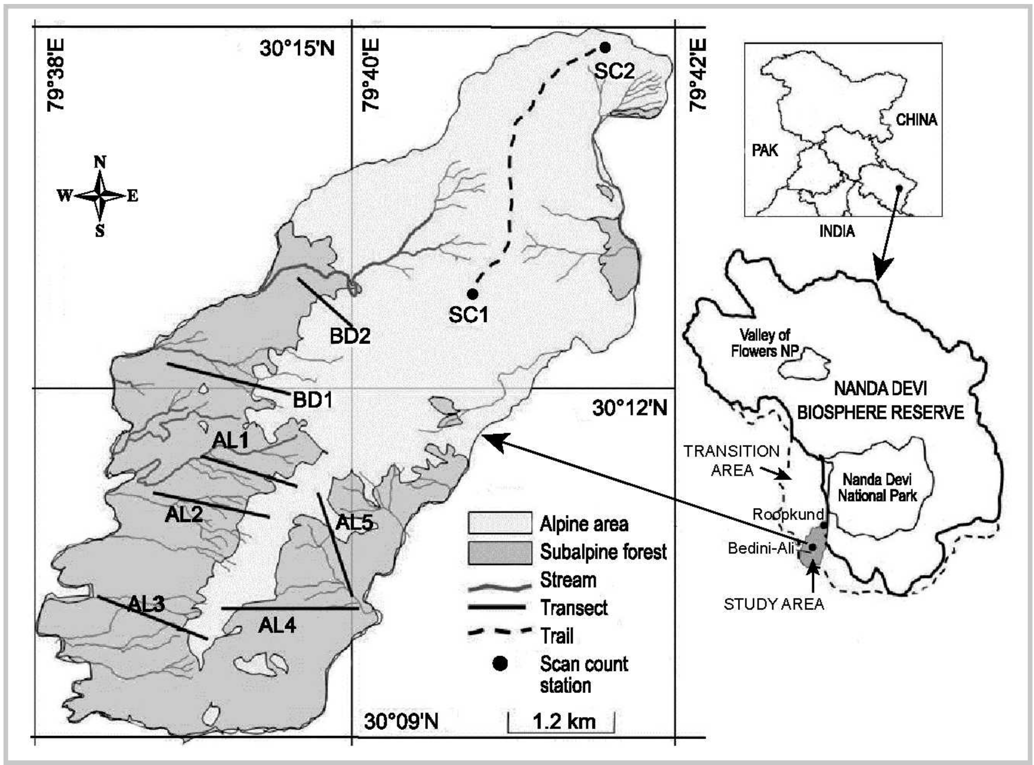


FIGURE 2 Map of Bedini-Ali, Nanda Devi Biosphere Reserve, India, showing the forests, alpine meadows, transects, and scanning points. (Map by authors)



horses, and mules) present in the alpine and subalpine zone of the study area was carried out once every month to estimate anthropogenic pressures. Disturbance variables (ie, cutting, lopping, and debarking of trees) on 10×10 m permanent plots ($n = 312$, 3 plots at 100-m intervals along each transect) and evidence of human presence along transects were recorded once in a season.

To estimate the relative abundance of wild ungulates the transects and trail (Burnham et al 1980) were surveyed within 2 hours of sunrise, and data on mountain ungulate species, number, sex, composition, sighting angle, and sighting distance were recorded. In addition, the scanning method (Sathyakumar 1994; Kittur et al 2010) was used to estimate relative abundance and the habitat use patterns of Himalayan *tahr* and blue sheep. This technique involves careful scanning on open grassy slopes or meadows and cliffs from vantage points, using spotting scopes and/or binoculars (8×40) for a specified period of time. During the study period, mountain ungulates were scanned from 2 vantage points between 06:00 and 09:00 h, and the area of the scan was measured using Survey of India toposheets. The scan duration varied from 1 to 3 hours depending on weather conditions. The number of animals seen and their age, sex, and group composition were recorded for every sighting. The various habitat parameters such as major vegetation types, elevation, aspect, slope categories, presence of livestock, and/or humans were also recorded for a 10-m radius around the animal sighted whenever possible. Transect, trail, and scan points were surveyed at least 3 times per month.

Dung count (Bennett et al 1940; Sathyakumar 1994) was used to estimate dung density of both wild and domestic ungulates along the transects. Dung counts were made within a 20×2 m belt transect every 100 m along the trail and transects. The pellet groups were removed after every count in order to avoid duplicate counting during the next sampling. Initial confusion in distinguishing between blue sheep pellets and livestock pellets was solved with the help of local herders and confirmations from experts at the Wildlife Institute of India, Dehradun, where samples of blue sheep dung were stored for identification purposes.

To assess habitat use by wild ungulates, altitude, aspect, slope, broad vegetation classes, percentage of tree cover, shrub cover, grass cover, rock cover, and livestock presence were sampled in three 10×10 m sample plots along the transects (as described above) and in one 10×10 m sample plot where evidence of wild ungulates was found.

Statistical analysis

Principal component analysis (SPSS 16.0) was used to extract one component from cutting, lopping, and debarking of trees using the covariance method. Extracted principal component along with livestock and human presence was further subjected to another

http://dx.doi.org/10.1659/MRD-JOURNAL-D-10-00069.1

TABLE 1 Characteristics of transects used for the study at Bedini-Ali, Nanda Devi Biosphere Reserve, India, 2005–2006.

Transect ID	Elevation (masl)	Length (km)	Aspect	Human use	Disturbance index
AL1	3160–3500	1.5	West	Low	−0.41
AL2	3150–3450	1.5	West	High	0.55
AL3	3090–3450	1.5	West	Low	−0.43
AL4	3000–3525	1.5	East	Moderate	−0.32
AL5	3000–3480	2.0	East	High	1.20
BD1	3200–3520	1.5	West	Low	−0.42
BD2	3000–3475	1.2	West	Moderate	−0.16

principal component analysis using the correlation method. Extracted overall index of disturbance was categorized into 3 disturbance classes: low, medium, and high.

Four surveys along each transect or scan point in each season were considered for estimation of detection probability for wild ungulates in different seasons, using PRESENCE 2.0 (Hines 2006). The encounter rate (number of animals/km) and overall density estimates (number of animals/km^2) were calculated using DISTANCE 4.0 (Thomas et al 2002). The relative density of blue sheep based on the scanning method was calculated as n/A (n = number of animal and A = scanning area) (Sathyakumar 1994; Kittur et al 2010). Dung density was estimated as follows: $D = n/A$, where n is the total number of pellet groups counted and A is the total area of the sample plots or belt transects (Sathyakumar 1994).

Nonmetric multidimensional scaling (NMS) was used to graphically represent differential habitat use by wild ungulates and livestock. Multidimensional scaling attempts to find the structure in a set distance measured between objects or cases. This is accomplished by assigning observations to specific locations in a conceptual space such that the distances between points in the space match the given similarities as closely as possible (Norussis 1997). NMS was run using the Sørensen distance measure and random starting configuration in "Autopilot" mode of PC-ORD 4.20 (McCune and Mefford 1999).

The presence of wild ungulates and livestock against the ordination scores obtained from the final solution of NMS are presented in a scatter plot. Habitat variable measurements and estimates such as altitude (m), slope (°), anthropogenic pressures (%), tree cover (%), shrub cover (%), grass cover (%), and rock cover (%) for 176 sites (where wild ungulate or livestock presence were recorded) were treated for NMS after carrying out log transformation. After 40 runs with real data, comparison of stress in relation to dimensionality (number of axis) and computation of a Monte Carlo test suggested a 2-dimensional solution for the data. The final solution (ordination scores for 176 sites) for 2 axes (coefficient of determination $r^2 = 0.97$) was produced after 84 iterations with a final stress of 7.02 and 0.00001 final instability.

Wild ungulate and livestock presence were plotted in scatter plots to visualize their distribution along these 2 axes. Wild ungulate presences recorded in the tree line zone were marked as "edge" points. Positioned below and above these "edge" points, marked points along the "grass cover and rock cover" axis were recorded in subalpine forest and alpine zone, respectively.

Results

Assessment of human use

Principal coordinates of overall human use were classified into 3 classes: low (< -0.04), moderate (≥ -0.04 to < 0), and high (≥ 0) (Table 1). In total, 4628 goats and sheep, 140 cattle (buffalo and cow), and 93 pack animals (horses and mules) used the alpine regions (3000–4000 m) of Bedini-Ali from May to October. The overall dung density estimated for livestock in the study area was 48.76 ± 14.13 pellet groups/ha; dung density estimation varied across seasons (Kruskal-Wallis $\chi^2 = 19.01$, df = 3, $p = 0.00$) and was highest in summer (166.87 ± 74.47 pellet groups/ha) and nil in winter.

Relative abundance of mountain ungulates

Only 2 groups of Himalayan *tahr* consisting of 10 and 16 individuals were sighted during the entire study period. Hence, Himalayan *tahr* was not included in further analysis. The detection probability of *sambar*, musk deer, and blue sheep did not vary significantly between spring, autumn, and winter (Kruskal-Wallis $\chi^2 = 1.43$, df = 2, $p = 0.49$) (Table 2). Detection probability for wild ungulates was not estimated for summer because of very low sample sizes. Blue sheep was the most commonly encountered [46 sightings, 652 individuals, 10.19 ± 1.20 (number/hour scan)] ungulate in the alpine regions followed by *sambar* [15 sightings, 18 individuals, 0.65 ± 0.01/km, 149 pellet

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TABLE 2 Detection probabilities (± SE) of wild ungulates in different seasons at Bedini-Ali, Nanda Devi Biosphere Reserve, India, 2005–2006.

Season	*Sambar*	Musk deer	Blue sheep
Winter	0.56 ± 0.09	0.59 ± 0.11	0.69 ± 0.14
Spring	0.33 ± 0.07	0.44 ± 0.14	0.48 ± 0.17
Autumn	0.53 ± 0.09	0.59 ± 0.11	0.48 ± 0.17

groups] in subalpine areas. Himalayan musk deer was sighted only on 3 occasions (3 individuals) (Table 3), and a total of 36 pellet groups were encountered during the study period. The average group size for blue sheep was 14.17 ± 1.57 individuals/group, ranging from 2 to 41 individuals.

Overall relative density (individuals/km^2) was estimated only for blue sheep (6.95 ± 0.82) and *sambar* (3.07 ± 0.97) in the study area. Relative density estimation (individuals/km^2) for blue sheep varied significantly in different seasons and was highest in winter (9.29 ± 0.75) and 0 in summer. Dung density estimates (pellet groups/ha) for *sambar* differed significantly (Kruskal-Wallis χ^2 = 16.11, df = 3, p = 0.01) between seasons, being highest in winter (28.57 ± 6.24) and lowest in summer (4.96 ± 1.91). Dung density estimates (pellet groups/ha) for musk deer were very low during spring (0.79 ± 0.54) but showed some increase during autumn (5.29 ± 1.73) and winter (5.16 ± 1.97), though the change was not statistically significant (Kruskal-Wallis χ^2 = 5.24, df = 3, p = 0.16).

Response of wild ungulates

Blue sheep density was inversely related to the abundance of livestock and other pack animals ($r_s = -0.67, p < 0.001, n = 32$), reaching its maximum in winter (9.29 ± 0.75 / km^2) in the absence of livestock and declining in summer under high livestock density (255.14 ± 14.27) (Figure 3). Dung density for *sambar* also showed an inverse relation to that of livestock ($r_s = -53, p < 0.001, n = 56$). Inverse relation ($r_s = -37, p = 0.01, n = 56$) was also present between musk deer dung density and livestock dung density.

Mountain ungulates differ in their use of altitude (Kruskal-Wallis χ^2 = 98.25, df = 3, p = 0.00). Box plots (Figure 4) showed that blue sheep (n = 28) used higher elevations (3700–4500 m) whereas musk deer (n = 22) and *sambar* (n = 71) both used elevations between 3100 and 3400 m. Livestock (n = 53) were herded at elevations between 3200 and 3500 m only.

Different aspect categories were pooled into 2 major categories, namely, eastern and western aspects, because the orientation of the study area was in a north-south direction. Most evidence of blue sheep (92.86%) was found in the eastern aspect, whereas all evidence of musk deer was found in the western aspect. Most evidence (64%) of *sambar* was found in the western aspect (one sample *t*-test for percentage; $t = 2.34, p = 0.02$) while herded livestock showed no significant difference (one sample *t*-test for percentage; $t = 0.14, p = 0.89$) in use of aspect categories.

Mountain ungulates differ significantly in use of slope categories ($\chi_L{}^2 = 43.56, p = 0.00$); more than 53% of the evidence for blue sheep was found on steep (31–45°) and very steep (46–60°) slopes. Most of the evidence (95%) for musk deer was found in 16–30° gentle and 0–15° flat slope categories, and 92% of the evidence for *sambar* was found on gentle and steep slopes. Most (90%) livestock evidence was found on flat (15%) and gentle (75%) slopes in the study area. *Sambar* used more tree cover and musk deer used more shrub cover; blue sheep never used tree and shrub cover, and herded livestock rarely used tree or shrub cover. Blue sheep used more rock cover, and herded livestock used more grass cover. The Mann-Whitney U -test showed significant differences for use of tree and shrub cover between *sambar* and musk deer and for use of grass cover and rock cover between blue sheep and livestock ($p \leq 0.001$ for all cases).

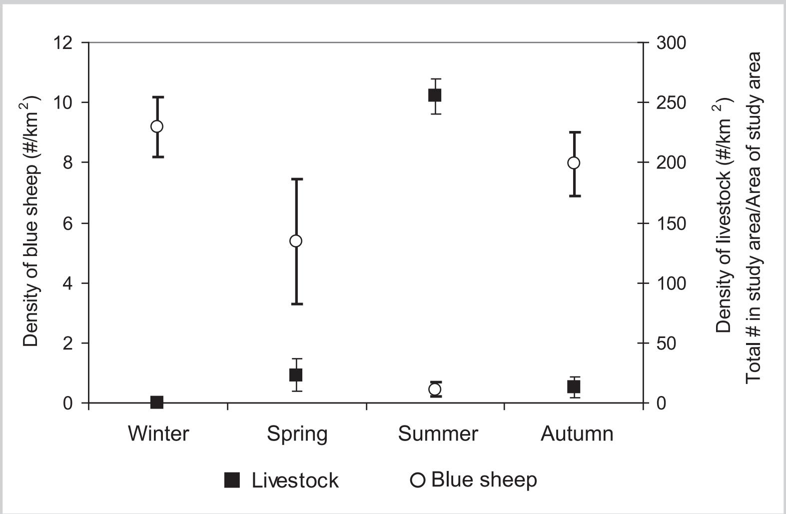
Habitat segregation between wild and domestic ungulates

Scores of different habitat variables in 2-dimensional final solutions of NMS represented increasing grass or rock cover against tree and shrub cover as axis 1 and

TABLE 3 Overall abundance (± SE) of wild ungulates at Bedini-Ali, Nanda Devi Biosphere Reserve, India, 2005–2006.

Species	Sightings	Density (no./km^2)	Encounter rate (ER) (no./km) or (no./h scan)	Group size
Blue sheep	46	6.95 ± 0.82	10.19 ± 1.20 (no./h scan)	14.17 ± 1.57
Musk deer	3	—	—	1
Sambar	15	3.07 ± 0.97	0.65 ± 0.0065 (no./km)	2
Himalayan *tahr*	3	—	—	2–16

FIGURE 3 Comparison of density of blue sheep and livestock in different seasons in Bedini-Ali, Nanda Devi Biosphere Reserve, India, 2005–2006.

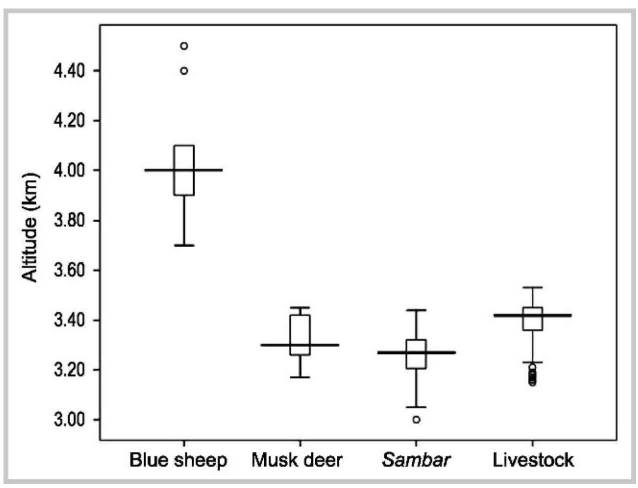


increasing anthropogenic pressures as axis 2 (Table 4). The scatter diagram (Figure 5) can be divided into 4 quadrants presenting 4 habitat and human use situations:

1. High grass cover or rock cover with low anthropogenic pressure
2. High grass and rock cover with high anthropogenic pressure
3. High tree and shrub cover with low anthropogenic pressures and
4. High tree and shrub cover with high anthropogenic pressure.

All blue sheep presence points were distributed in the first quadrant (high grass and rock cover with low anthropogenic pressure; alpine zone). Most of the livestock presence points were concentrated in the second quadrant (high grass and rock cover with high anthropogenic pressures; alpine zone). Most of the *sambar* presence points were distributed in the third quadrant (high tree and shrub cover with low anthropogenic pressure; subalpine forest). Musk deer presence points were scattered in all 4 quadrants, but a majority (50%) of the presence points (recorded in the edge and subalpine forest) were in the fourth quadrant (high tree and shrub cover with high anthropogenic pressure).

FIGURE 4 Use of altitude by wild ungulates and livestock in Bedini-Ali, Nanda Devi Biosphere Reserve, India, 2005–2006.



Discussion and recommendations

Negative correlation of all wild ungulate abundance with livestock abundance implies negative response of wild ungulates to livestock grazing. The presence of more than 4000 livestock accompanied by herders and shepherd dogs and consequent habitat degradation may be one of the causes of low abundance of wild ungulates in the study area.

TABLE 4 Scores of different habitat variables in 2-dimensional final solution of NMS.

Habitat variables	Axis 1	Axis 2
Anthropogenic pressure	−0.03	0.26
Altitude	0.06	0.00
Slope	0.00	−0.03
Trees	−0.86	−0.13
Shrubs	−0.68	−0.05
Grass	0.20	0.07
Rocks	0.46	0.00

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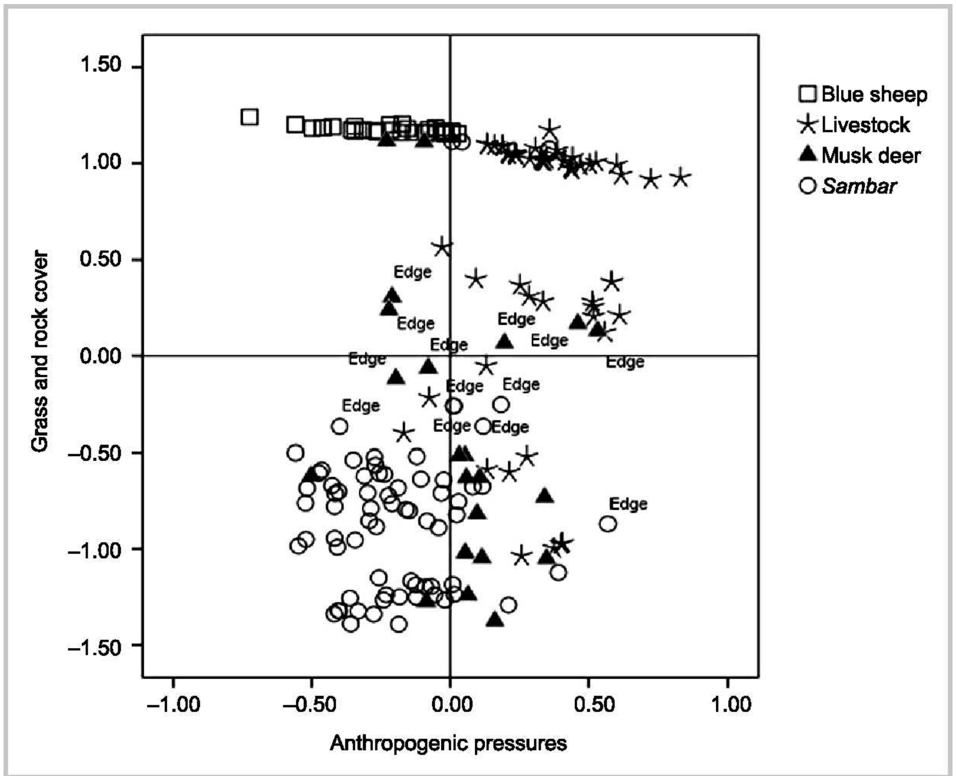
FIGURE 5 Distribution of wild ungulates and livestock presence along the 2 axes of habitat variables derived from final solution of NMS.



Apart from the obvious negative impact of anthropogenic activities, very low abundance of wild ungulates recorded in summer may be the result of very poor visibility due to mist. Inverse relation of dung density for wild ungulates and livestock, particularly during summer, may be the result of greater decomposition rates of pellets in the summer due to high temperature and heavy rainfall, but for domestic ungulates the climatic effects on pellets may be masked by peaks in their numbers. However, Green (1987) reported negligible use of latrines by musk deer during summer, and this behavior may have resulted in very low detection of musk deer presence during summer. As both *sambar* and musk deer were most likely resident in the study area, less evidence of their presence during summer may not necessarily point toward population decline in the study area. It is also likely that the natural shift of habitat use by wild ungulates might have caused their absence in the study area during summer. This is particularly important in light of the relatively small spatial coverage of the study.

Comparison of abundance estimates for blue sheep in Nanda Devi National Park (no livestock grazing) and Bedini-Ali (> 4000 livestock) clearly indicates higher abundance (density and encounter rate [ER]) and larger group size in Nanda Devi National Park than in Bedini-Ali. Similarly, abundance and dung ER estimates for Himalayan musk deer were also higher in Nanda Devi National Park as well as in Kedarnath Wildlife Sanctuary (1000–3000 livestock) than in Bedini-Ali (Table 5).

During late spring, summer, and early autumn livestock are herded in all available higher and lower, gentle, and steep alpine meadows that generally have high grass cover. From early winter to early spring, blue sheep were recorded as using the same alpine meadows (earlier used by livestock in summer), which were situated at higher elevations with steep slopes and greater rock cover but with low grass cover (already depleted by livestock). Blue sheep were never found to use lower alpine meadows with comparatively high grass cover, gentle slope, and low rock cover. After the beginning of livestock grazing in late spring, blue sheep started using high-altitude steep and rocky terrain in the northern part of the study area. Many observations (Schaller 1977; Jackson and Ahlborn 1987; Paudyal and Bauer 1988; Bauer 1990; Prins 1992; Mishra 2001; Bagchi et al 2002; Raghavan 2003) imply that livestock-grazing patterns have affected distribution and abundance of wild ungulates considerably in the past. In Kedarnath Wildlife Sanctuary, Kittur et al (2010) observed that during late autumn and winter, Himalayan *tahr* used areas that were heavily grazed by livestock and heavily used by tourists in the summer. The presence of *tahr* in these areas indicated that *tahr* were sensitive to disturbances and avoided these areas in spring, summer,

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TABLE 5 Comparison between the abundance estimates of blue sheep, Himalayan musk deer, and Himalayan *tahr* in Nanda Devi National Park, Kedarnath Wildlife Sanctuary and Bedini-Ali, Nanda Devi Biosphere Reserve, India, 2005–2006.

Protected Area	Livestock	Species	Density (no./km^2)	ER[c] (no./km)	Dung ER[c] (no./km)	Group size
Nanda Devi NP[a]	0	Blue sheep	>20	0–26.4	1.3–54.4	4–61
		Himalayan musk deer	>4	0.2	2.2–4.9	—
		Himalayan *tahr*	—	1.7–3.5	0–3.8	1–17
Kedarnath WS[b]	1000–3000	Blue sheep	—	—	—	—
		Himalayan musk deer	3.2–3.7	0.1	—	—
		Himalayan *tahr*	10–16	23.5–27.5	0–3.5	6.1–13.7
Bedini-Ali	>4000	Blue sheep	0–9	0–5.47	0–2.93	3–41
		Himalayan musk deer	<1	0.02	0.4–0.6	—
		Himalayan *tahr*	—	—	—	2–16

[a]Sathyakumar 2004.
[b]Sathyakumar 1994; Kittur et al 2010.
[c]ER = encounter rate.

and early autumn, that is, at the peak livestock grazing period. However, as livestock grazing has been practiced for a long period of time in this area, it is difficult to decide whether blue sheep have been competitively excluded from alpine meadows with more grass cover and gentler slopes because of livestock-grazing pressure and disturbances, or whether they naturally use alpine meadows with greater rock cover and steep slopes.

Sambar and Himalayan musk deer rarely extend beyond the subalpine and *krummholz* zones. In Figure 5 the presence of both musk deer and *sambar* in quarters of high anthropogenic pressure indicates some degree of overlap between wild ungulate habitat use and anthropogenic disturbances in tree line and subalpine forest habitats in the study area. *Sambar* were found to use steeper slopes at lower elevations with dense tree cover where livestock grazing was generally not practiced. Musk deer were found to use gentle to steep slopes at higher elevations with dense *Rhododendron campanulatum* shrub cover located along and beyond the tree line of the western aspect. Most of the temporary shelters of livestock herders were situated in the tree line zone of the eastern aspect; thus the high degree of anthropogenic pressures in terms of cover removal due to cutting and lopping and direct threat of predation from the presence of shepherd dogs may cause musk deer to avoid the tree line habitat of the eastern aspect. Solitary and territorial nature, very restricted habitat use patterns, and constant threats from anthropogenic activities resulted in musk deer being the most elusive and rarely seen animal in the study area. In the neighboring Kedarnath Wildlife Sanctuary, Green (1985) and Sathyakumar et al (1993) also reported musk deer as very sensitive to disturbances and found that this species occurs in low densities in areas that are subjected to high levels of livestock grazing pressure.

Conservation implications

The Bedini-Ali meadows are very important from ecological, economic, and sociocultural perspectives. In accordance with the concepts and norms of the management of a Biosphere Reserve, this area will be managed taking into consideration the sustainable development of the resident communities. It is extremely important to recognize the role of wild mountain ungulates in these high-altitude forest and alpine habitats, as they are prey for large carnivores and use the same grazing resources as domestic livestock (Sathyakumar et al 1993). The potential impact of anthropogenic activities on the demographics and long-term survival of wild ungulates is highly dependent on the types of behavioral shifts that are produced. Therefore, in future assessment of the mechanism by which the various forms of human disturbance bring about changes in social structure, the mating system, fecundity, and other life-history traits of different wild ungulates should be a prerequisite for their conservation.

From our findings it cannot be concluded whether further increase in the livestock population will negatively affect the rangelands by reducing their productivity and quality, consequently affecting the livestock and wildlife populations in the Bedini-Ali region. Thus, prediction of the threshold level for anthropogenic activities should be determined by long-term study in this area. For the present scenario, instead of a complete ban on grazing in any particular area, we propose rotational grazing, as alternate pastures are available in the vicinity of Bedini-Ali.

http://dx.doi.org/10.1659/MRD-JOURNAL-D-10-00069.1

Reducing duration of stay and regulating livestock numbers by setting a limit on the numbers of goats and sheep grazing in a locality are among the measures that could reduce the pressure of intense grazing (Sathyakumar et al 1993). A recent study on pastoral practices, wild mammals, and the conservation status of alpine meadows in the western Himalaya (Rawat 2007) showed that most alpine meadows were heavily grazed during summer and that abundance of wild mammals was very low in heavily grazed and degraded PAs. Without the rationalization of the present practice of livestock grazing by management authorities in consultation with the local communities, several sites in the Himalaya would fail to meet conservation objectives and alpine meadows would further degrade, leading to environmental disaster in the region. In the context of this critical scenario, there are also some instances where proper management interventions served very well to meet conservation objectives for ungulate species in the alpine and subalpine forests of Western Himalaya. Twenty-five years of intermittent reduced grazing led to recovery of the *tahr* population and expansion in its distribution range in Kedarnath Wildlife Sanctuary (Kittur et al 2010). A total ban on anthropogenic activities inside Nanda Devi National Park since 1983 also resulted in improvement in wild ungulate abundance estimates (Sathyakumar 2004).

Large numbers of tourists visit the Bedini-Ali area from April to December every year. Camping and littering by tourists in these areas caused considerable damage to the Bedini meadow, where strict regulation is needed. Tourism can serve as an important alternative source of livelihood for the local people if proper training of local youth and capacity building for ecotourism were to be carried out by the government or nongovernmental organizations. In eastern Himalaya, there are instances where traditional yak herders were evicted from alpine pastures inside the Khangchendzonga National Park, Sikkim, India, and successfully trained and rehabilitated to manage ecotourism as an alternative livelihood (Tambe 2007). Thus, in the Bedini-Ali region, proper long-term management interventions through systematic execution may improve the status of wild ungulates. With local people who are already motivated to conserve the alpine meadows, and with the option of ecotourism as an alternative livelihood strategy, proper management interventions would prevent further degradation of the alpine habitats of Bedini-Ali and ensure long-term sustainable use of the meadows for livestock and human use.

ACKNOWLEDGMENTS

We thank Dr R. K. Rai, Director (CS), Ministry of Environment and Forests, Government of India, for funding support for this project. We thank the Uttarakhand State Forest Department for granting us the permission and providing the necessary help and support to carry out this work at NDBR. In this regard, we thank the CWLW, Director, NDBR, and DFOs of Nanda Devi NP and Badrinath Forest Division for their cooperation. We thank Shri P. R. Sinha, Director WII, and Dr V. B. Mathur, Dean WII, for providing us with the necessary facilities and support for smooth conduct of this project. We thank Shri Than Singh Bisht, of Wan village, for his help in the field work. Finally, we also thank the 2 anonymous reviewers for their valuable comments on the manuscript.

REFERENCES

Bagchi S, Mishra C, Bhatnagar YV. 2004. Conflicts between traditional pastoralism and conservation of Himalayan ibex (*Capra sibirica*) in the Trans-Himalayan mountains. *Animal Conservation* 7(2):121–128. doi:10.1017/S1367943003001148.

Bagchi S, Mishra C, Bhatnagar YV, McCarthy T. 2002. *Out of Steppe? Pastoralism and Ibex Conservation in Spiti.* CERC Technical Report No. 7. Mysore and Dehradun, India, and Seattle, WA: Nature Conservation Foundation, Wildlife Institute of India, and International Snow Leopard Trust.

Bauer JJ. 1990. The analysis of plant-herbivore interactions between ungulates and vegetation on alpine grasslands in the Himalayan region of Nepal. *Plant Ecology* 90(1):15–34. doi:10.1007/BF00045586.

Bennet LJ, English PF, McCoun R. 1940. A study of deer populations by pellet group counts. *Journal of Wildlife Management* 4:398–403

Bhattacharya T, Sathyakumar S, Rawat GS. 2007. *Studies on Animal Habitat Interactions in the Buffer Zone of Nanda Devi Biosphere Reserve.* Final Report. Dehradun, India: Wildlife Institute of India.

Bhattacharya T, Sathyakumar S, Rawat GS. 2009. Distribution and abundance of Galliformes in response to anthropogenic pressures in the buffer zone of Nanda Devi Biosphere Reserve. *International Journal of Galliformes Conservation* 1:78–84.

Burnham KP, Anderson DR, Laake JL. 1980. Estimation of density from line transects sampling of biological population. *Wildlife Monograph* 72:1–202.

Green MJB. 1985. *An Aspect of the Ecology of Himalayan Musk Deer* [PhD thesis]. Cambridge, United Kingdom: Cambridge University.

Green MJB. 1987. Diet composition and quality in Himalayan musk deer based on fecal analysis. *Journal of Wildlife Management* 51(4):880–892.

Hines JE. 2006. *PRESENCE 2.0 USGS.* Laurel, MD: Patuexent Wildlife Research Centre.

Jackson R, Ahlborn G. 1987. *A High Altitude Wildlife Survey of the Hongu Valley with Special Emphasis on Snow Leopard.* Report to HMG (His Majesty's Government). Kathmandu, Nepal: Department of National Parks and Wildlife Conservation (DNPWC), King Mahendra Trust (KMTNC).

Kala CP, Rawat GS. 1999. Effects of livestock grazing on the species diversity and biomass production in the alpine meadows of Garhwal Himalaya, India. *Tropical Ecology* 40:69–74.

Kittur S, Sathyakumar S, Rawat GS. 2010. Assessment of spatial and habitat use overlap between Himalayan Tahr and livestock in Kedarnath Wildlife Sanctuary, India. *European Journal of Wildlife Research* 56:195–204. doi:10.1007/s10344-009-0302-3.

McCune B, Mefford MJ. 1999. *PC-ORD. Multivariate Analysis of Ecological Data.* Version 4.0. MjM Software. Gleneden Beach, OR: [no publisher].

Mehra BS. 2000. *Livestock Grazing and Conservation of Biodiversity in the High Altitude Ecosyatem—An Integrated Landscape Management Approach* [PhD thesis]. Dehradun, India: Wildlife Institute of India, Dehradun.

Mishra C. 2001. *High Altitude Survival: Conflicts between Pastoralism and Wildlife in the Trans-Himalaya* [PhD thesis]. Wageningen, The Netherlands: University of Wageningen.

Mishra C, Wieren SEV, Ketner P, Heitkönig IMA, Prins HHT. 2004. Competition between domestic livestock and wild bharal *Pseudois nayaur* in the Indian trans-Himalaya. *Journal of Applied Ecology* 41(2):344–354. doi:10.1111/j.0021-8901.2004.00885.x.

Namgail T, Fox JL, Bhatnagar YV. 2007. Habitat shift and time budget of the Tibetan argali: The influence of livestock grazing. *Ecological Research* 22(1):25–31. doi:10.1007/s11284-006-0015-y.

Norussis MJ. 1997. *Statistical Package for Social Sciences (SPSS) 7.5.* Chicago, IL: SPSS.

Owen-Smith N. 1979. Assessing the foraging efficiency of a browsing ungulate, the kudu. *South African Journal of Wildlife Research* 9:102–110.

Packlatko T, Nievergelt B. 1985. Time budgeting, range use pattern and relationships with groups of individually marked chamois. *In:* Lovari S, editor. *The Biology and Management of Mountain Ungulates*. London, United Kingdom: Croom Helm, pp 93–101.
Paudyal D, Bauer JJ. 1988. *A Survey of Wildlife, Grasslands and Pastoral Systems of the Upper Hinku and Hongu Valleys.* Field Document No. 15. Kathmandu, Nepal, and Rome, Italy: Department of National Parks and Wildlife Conservation (DNPWC), Food and Agricultural Organization.
Prins HHT. 1992. The pastoral road to extinction: Competition between wildlife and traditional pastoralism in East Africa. *Environmental Conservation* 19:117–123
Raghavan B. 2003. *Interaction between Livestock and Ladakh Urial* (Ovis vignei vignei) [MSc thesis]. Rajkot, India: Saurashtra University.
Rawat GS. 2007. Pastoral practices, wild mammals and conservation status of alpine meadows in Western Himalaya. *Journal of Bombay Natural History Society* 104(1):5–11
Sathyakumar S. 1993. Status of mammals in Nanda Devi National Park. *In:* Scientific and Ecological Expedition to Nanda Devi. A Report. Dehradun, Wildlife Institute of India, pp 5–15.
Sathyakumar S. 1994. *Habitat Ecology of Major Ungulates in Kedarnath Musk Deer Sanctuary, Western Himalaya* [PhD thesis]. Rajkot, India: Saurashtra University, Rajkhot.
Sathyakumar S. 2004. Conservation status of mammals and birds in Nanda Devi National Park: An assessment of changes over two decades. *In:* Biodiversity Monitoring Expedition Nanda Devi 2003. A Report. Dehradun, Wildlife Institute of India, pp 1–14.
Sathyakumar S, Prasad SN, Rawat GS, Johnsingh AJT. 1993. Conservation status of Himalayan musk deer and livestock impacts in Kedarnath Wildlife Sanctuary, Western Himalaya. *In:* Pangtey YPS, Rawal RS, editors. *High Altitude of the Himalaya*. Nainital, India: Gyanodaya Prakashan, pp 240–245.
Schaller GB. 1977. *Mountain Monarchs: Wild Sheep and Goat of the Himalayas*. Chicago, IL: University of Chicago Press.
Shrestha R, Wegge P. 2008. Habitat relationships between wild and domestic ungulates in Nepalese trans-Himalaya. *Journal of Arid Environments* 72:914–925.
SPSS [Statistical Package for Social Sciences]. 1997. *SPSS for Windows*. Version 16.0. Chicago, IL: SPSS.
Tambe S. 2007. *Alpine Vegetation Ecology and Livestock Grazing in Khangchendzonga National Park, Sikkim* [PhD thesis]. Dehradun, India: Forest Research Institute (FRI) University.
Thomas L, Laake JL, Strindberg S, Marques FFC, Buckland ST, Borchers DL, Anderson DR, Burnham KP, Hedley SL, Pollard JH. 2002. Distance 4.0. Release "x"1. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/; accessed May 2011.
ZSI [Zoological Survey of India]. 1995. *Fauna of Nanda Devi Biosphere Reserve*. Dehra Dun, India: Zoological Survey of India, Northern Regional Station.